

BEST AVAILABLE COPY

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
1 August 2002 (01.08.2002)

PCT

(10) International Publication Number
WO 02/059456 A1

(51) International Patent Classification⁷: **E21B 43/10**

en Roderijs (NL). MACKENZIE, Alan [GB/GB]; 2 Con-
tlaw Place, Milltimber, Aberdeen AB13 0DS (GB).

(21) International Application Number: PCT/GB02/00356

(22) International Filing Date: 28 January 2002 (28.01.2002)

(74) Agent: **MURGITROYD & COMPANY**; 165-169 Scot-
land Street, Glasgow G5 8PL (GB).

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0102021.3 26 January 2001 (26.01.2001) GB

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,
CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM,
HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK,
LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX,
MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL,
TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(71) Applicant (*for all designated States except US*): **E2
TECH LIMITED** [GB/GB]; Shell International B.V., PO
Box 384, NL-2501 CJ The Hague (NL).

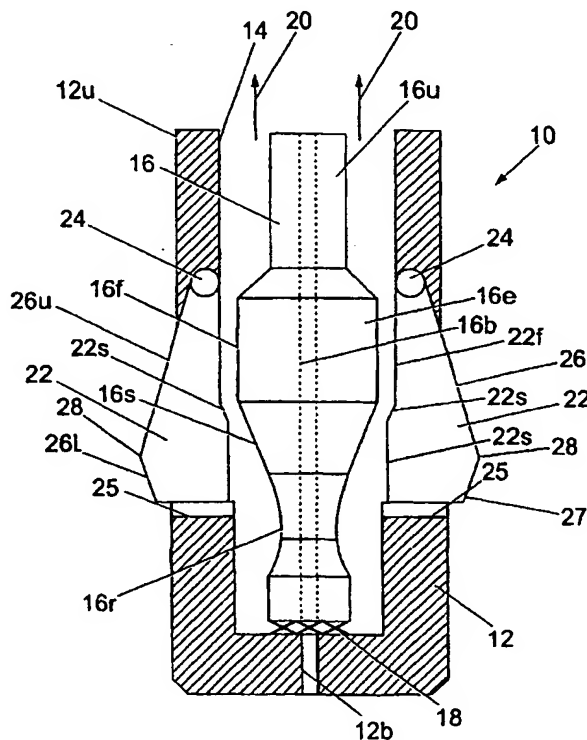
(84) Designated States (*regional*): ARIPO patent (GH, GM,
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **OOSTERLING, Pe-
ter** [NL/NL]; Noordeindseweg 128, NL-2651 CX Berkel

[Continued on next page]

(54) Title: EXPANDER DEVICE



(57) Abstract: Apparatus (9) for radially expand-
ing an expandable member, the apparatus including
a plurality of radially moveable fingers (22). The
radially moveable fingers (22) can move between
two positions; in a first position, the moveable fin-
gers (22) are radially extended to a form a cone to
facilitate radial expansion of the expandable mem-
ber; in the second position, one or more of the radi-
ally movable fingers (22) can move radially inward
so that restrictions in the path of the apparatus can
be by-passed.

WO 02/059456 A1

(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,
NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

EXPANDER DEVICE

1
2
3 The present invention relates to apparatus that is
4 particularly suited for radially expanding expandable
5 members, such as liners, casings, tubulars and the
6 like.
7
8 It is known to use an expander device to expand at
9 least a portion of an expandable member. Expandable
10 members are typically of a ductile material so that
11 they can undergo plastic and/or elastic deformation
12 using an expander device. Expandable members can
13 include liner, casing, drill pipe and other tubulars.
14 Use of the term "expandable member" herein will be
15 understood as being a reference to any one of these
16 and other variants that are capable of being radially
17 expanded by application of a radial expansion force,
18 generally applied by the expander device, such as a
19 cone. An expandable member is typically used within
20 a borehole either to complete an uncased portion of a
21 borehole, or to repair a damaged portion of a pre-
22 installed liner or casing, for example.

1
2 The initial outer diameter (OD) of the expandable
3 member is typically less than the inner diameter (ID)
4 of the borehole, or a pre-installed portion of liner,
5 so that the expandable member can be run into the
6 borehole. An expander device can then be forced
7 through the expandable member, and at least a portion
8 of the expander device has an OD that is typically
9 the same as, or slightly less than, the ID of the
10 uncased borehole or previously installed liner.
11 Thus, as the expander device passes through the
12 expandable member, the OD of the expandable member is
13 increased so that an outer surface of the expandable
14 member is pressed against an inner wall of the
15 uncased borehole, or the inner surface of the pre-
16 installed liner.

17
18 Prior art expander devices are typically of a hard
19 material, such as tungsten carbide, and are typically
20 of a solid construction, for example a solid cone.
21 As the expander device (e.g. a cone) is pushed or
22 pulled through the expandable member, it can become
23 stuck due to, for example, immovable portions of the
24 inner wall of the uncased borehole that protrude
25 inwards into the path of the expander device.

26
27 In such a case, the travel of the expander device may
28 be restricted by the inward protrusion, and as a
29 result, the expansion process cannot be completed, as
30 the device becomes stuck at the protrusion.

31

1 When the expander device becomes stuck, it is
2 necessary to retrieve the device from the borehole,
3 typically by a fishing operation. Fishing operations
4 generally require the expander device to be detached
5 from a drill string or the like that is used to push
6 or pull the expander device through the expandable
7 member. Once the expander device has been detached,
8 the drill string can be removed from the borehole,
9 thus leaving the expander device therein. Clearly,
10 the expander device must also be removed from the
11 borehole to allow the recovery of hydrocarbons
12 therefrom.

13
14 A typical fishing operation may involve the use of a
15 tungsten carbide wash over-mill that is attached to
16 an end of a drill string. The wash over-mill is
17 rotated with the drill string, and the mill is
18 inserted into the borehole to engage the obstruction
19 and cut it away at its outer edges. However, as the
20 wash over-mill cutters are generally made from the
21 same material as the expander cone, they wear quickly
22 and so this type of fishing operation is problematic.

23
24 Although other types of conventional fishing
25 operations may be used, they all have a number of
26 disadvantages. If the expander device does become
27 stuck, the drill string used to push or pull it must
28 be fully removed from the borehole, once the expander
29 device has been detached. Boreholes can be many
30 kilometres in length, and removal of the string in
31 such cases is a very time consuming operation.

1 Thereafter, the stuck expander device must be
2 retrieved using a conventional fishing operation.
3 Having retrieved the expander device, a new device is
4 attached to the end of the drill string, which is
5 then lowered into the borehole to allow the expansion
6 of the expandable member to continue. It may also be
7 necessary to remove the obstruction (e.g. by using a
8 wash over-mill) before the expansion process can
9 continue.

10

11 This process results in a long rig downtime which can
12 be very expensive due to the high costs involved,
13 particularly on offshore rigs.

14

15 According to a first aspect of the present invention,
16 there is provided apparatus for expanding an
17 expandable member, the apparatus comprising a first
18 member, one or more radially movable portions, a
19 second member, and force isolating means acting
20 between the first and second members.

21

22 The first member typically comprises a housing. The
23 housing may comprise a cylindrical member with a
24 blind bore. The isolating means is typically coupled
25 between a first end of the second member and the
26 blind end of the bore. Alternatively, the isolating
27 means is coupled between a lower face of the first
28 member, and a face provided on the second member.

29

30 The second member typically comprises a shaft having
31 a cone that bears against the radially movable

1 portions (typically fingers pivotally mounted on the
2 first member). The shaft and cone typically move
3 axially with respect to the first member in and out
4 of engagement with the radially movable portions
5 (e.g. the fingers).

6
7 A second end of the second member is typically
8 provided with attachment means for attaching the
9 apparatus to a drill string or the like. The
10 attachment means may comprise any conventional means
11 such as screw threads (e.g. box and/or pin
12 connections) or the like.

13
14 The fingers are typically coupled to the first member
15 so that they can move in a radial and/or axial
16 direction. Thus, the fingers can expand or contract
17 to adjust an outer diameter of the apparatus.
18 Typically, the fingers are held in a radially
19 expanded position by the cone on the second member
20 moving axially with respect to the first member to a
21 first position in which the spring is contracted. In
22 that first position, an outer surface of the cone
23 abuts against an inner surface of the fingers and
24 prevents them from moving radially inward. However,
25 solid protrusions in the path of the fingers cause
26 the force in the axial direction applied to the
27 second member to extend the spring where the axial
28 force exceeds the force of the spring. As the spring
29 extends, the second member moves axially under the
30 axial pulling force, and the cone moves to a second
31 position that allows the fingers to move radially

1 inward to bypass the restriction. As the restriction
2 is passed, the axial pulling force drops below the
3 biasing force of the spring as the force that is
4 retarding the apparatus is overcome, the spring
5 contracts and the second member moves into engagement
6 with the fingers causing them to move radially
7 outward to the radially expanded position.
8 Additionally, the engagement of the fingers with the
9 restriction can cause them to move inwards against
10 the cone thereby moving it to the second position in
11 which the spring is extended. In this way, if the
12 apparatus encounters a restriction or the like, the
13 fingers can retract until the apparatus has passed
14 the restriction and then expand once passed.

15
16 By selecting the strength of the spring, the
17 apparatus can be programmed to move the fingers at a
18 given axial force that is typically greater than the
19 force used to push or pull the apparatus. The given
20 axial force can take into account the retarding force
21 applied to the second member due to the obstruction.

22
23 The fingers are typically pivotally coupled to the
24 first member using a pivot, such as a pivot pin,
25 hinge or the like. Optionally, a biasing means may
26 be provided to bias the fingers radially outward.
27 The biasing means may comprise a torsion spring that
28 is positioned at the pivot.

29
30 An outer face of the fingers typically defines a
31 cone. The outer faces of the fingers are typically

1 angled so that the cone formed thereby faces in the
2 direction of travel of the apparatus. Thus, as the
3 apparatus is moved in the direction of travel, the
4 outer faces engage an inner wall of the expandable
5 member or the like to expand the expandable member.
6

7 Optionally, the outer faces may include a second
8 sloping face that is angled so that the apparatus can
9 expand the inner diameter of the tubular when moved
10 in the opposite direction to the normal direction of
11 travel. In this embodiment, there is provided a
12 double-sided cone that can be used in either
13 direction of travel to expand the expandable member.
14

15 The cone of the second member typically comprises an
16 enlarged diameter portion. The enlarged diameter
17 portion is preferably located so that it is aligned
18 on the axis of the apparatus with the fingers. The
19 enlarged diameter portion is provided with an outer
20 profile that allows the fingers to move inwards when
21 the second member is moved axially within the first
22 member. Thus, the fingers can contract to allow the
23 apparatus to pass restrictions or obstructions. An
24 inner face of the fingers is typically provided with
25 a corresponding profile.
26

27 The outer profile typically comprises a flat portion
28 extending in the axial direction, and a sloping
29 portion. The profile on the inner face of the
30 fingers typically comprises a flat portion extending
31 in the axial direction, and a sloping portion. The

1 sloping portion is preferably set at a shallow angle.
2 In use, the flat portion and the sloping portion
3 provided on the enlarged diameter portion engage
4 respectively with the flat portion and the sloping
5 portion provided on the inner face of the fingers.
6 Thus, the second member supports the fingers in the
7 radially expanded position during the expansion
8 process. When the apparatus encounters a restriction
9 or obstruction, the second member (and the enlarged
10 diameter portion thereof) moves in the direction of
11 travel or load. As the enlarged diameter portion
12 moves axially out of engagement with the inner face
13 of the fingers, at least the sloping portions of the
14 respective profiles on the enlarged diameter portion
15 and the inner face of the fingers disengage. This
16 allows the fingers to contract as they can move
17 radially inward into the space created by axial
18 movement of the enlarged diameter portion.
19
20 According to a second aspect of the present
21 invention, there is provided apparatus for expanding
22 an expandable member, the apparatus comprising a
23 body, one or more radially movable portions, and
24 force isolating means acting between the body and the
25 or each radially moveable portion.
26
27 The force isolating means typically provides a
28 biasing force to the or each radially moveable
29 portion. The force required to move the or each
30 radially moveable portion inwards is typically

1 greater than the biasing force of the force isolating
2 means.

3

4 Force applied to the body is typically transmitted to
5 the or each radially moveable portion through the
6 isolating means, and the radial position of the or
7 each radially movable portion is typically at least
8 partially controlled by the biasing force of the
9 force isolating means. Force applied to the body can
10 be isolated from the or each radially moveable
11 portion by the force isolating means.

12

13 The isolating means typically comprises a resilient
14 member that allows relative movement between the body
15 and the or each radially moveable portion, preferably
16 in an axial direction. The resilient member may
17 comprise a spring. The resilient member typically
18 has a biasing force that is greater than a maximum
19 load that will be applied to the apparatus. Thus,
20 when the maximum load is reached and exceeded, the
21 biasing force of the resilient member is overcome,
22 and the resilient member deforms (e.g. extends or
23 contracts) in the direction of the load.

24

25 Alternatively, the isolating means comprises a fluid
26 chamber that is in communication with the or each
27 radially moveable portion. The fluid chamber is
28 preferably in fluid communication with a spring
29 means. The spring means typically comprises a first
30 chamber, a floating piston in communication with the
31 first chamber, and a second chamber in communication

1 with the piston. The first chamber typically
2 contains fluid and is in fluid communication with the
3 fluid chamber that is in communication with the or
4 each radially moveable portion. The second chamber
5 typically includes a spring. The spring may be
6 mechanical, hydraulic, pneumatic or the like.

7
8 In this embodiment, as the radially moveable portions
9 are forced inward due to a restriction, they act on
10 the fluid in the fluid chamber, forcing the fluid
11 into the first chamber. The displacement of fluid
12 causes the piston to compress the spring in the
13 second chamber and this allows the radially moveable
14 portions to move inwards, thus passing the
15 restriction. Once the restriction has been passed,
16 the spring extends forcing fluid in the first chamber
17 to be transferred to the fluid chambers, thus forcing
18 the radially moveable portions outwards.

19
20 The biasing force of the force isolating means is
21 typically provided by the spring. Optionally, the
22 biasing force of the spring may be varied.

23
24 In an alternative embodiment, the isolating means
25 comprises a hydraulic spring. The hydraulic spring
26 typically comprises an inflatable element that is in
27 fluid communication with a fluid chamber. The fluid
28 chamber is typically filled with a fluid (e.g. oil)
29 that is typically incompressible. The fluid in the
30 fluid chamber acts on a floating piston that is

1 located in a second chamber. The second chamber is
2 typically filled with a fluid, preferably gas.

3
4 In this embodiment, as the radially moveable portions
5 are forced inwards due to a restriction, they act on
6 the fluid in the inflatable element, forcing fluid
7 into the fluid chamber. The displacement of fluid
8 into the fluid chamber acts on the piston, causing it
9 to compress the fluid in the second chamber. This
10 allows the radially moveable portions to move
11 inwards, thus passing the restriction. Once the
12 restriction has been passed, the fluid in the second
13 chamber expands, forcing the piston to act on the
14 fluid in the fluid chamber, the fluid typically being
15 transferred to the inflatable element, thus forcing
16 the radially moveable portions outwards.

17
18 The biasing force of the force isolating means is
19 typically provided by the fluid in the second
20 chamber. Optionally, the biasing force can be
21 varied, typically by varying the amount of fluid in
22 the second chamber.

23
24 The body may comprise a cylindrical member, and the
25 or each radially moveable portion is typically
26 pivotably mounted to the body.

27
28 The apparatus optionally includes a second member
29 that typically comprises a shaft. The shaft
30 typically houses at least a portion of the isolating
31 means. In one embodiment, the shaft houses the fluid

1 chamber that is in communication with the or each
2 radially moveable portion, and the spring means. In
3 an alternative embodiment, the shaft houses a
4 hydraulic spring.

5
6 A second end of the shaft is typically provided with
7 attachment means for attaching the apparatus to a
8 drill string or the like, although the attachment
9 means may be provided on the body. The attachment
10 means may comprise any conventional means such as
11 screw threads (e.g. box and/or pin connections) or
12 the like.

13
14 The or each radially moveable portion typically
15 comprises one or more fingers. The or each finger is
16 typically coupled to the body so that they can move
17 in a radial and/or axial direction. Thus, the or
18 each finger can expand or contract to adjust an outer
19 diameter of the apparatus. Typically, the or each
20 finger is held in a radially expanded position by the
21 fluid in the fluid chamber or the inflatable element.
22 In this position, the fluid in the inflatable element
23 or the fluid chamber abuts against an inner surface
24 of the or each finger and prevents them from moving
25 radially inward. However, the fingers can move
26 radially inward against the biasing force of the
27 hydraulic spring or the spring means, provided that
28 the force acting on the fingers produced by
29 engagement with the restriction is sufficient to
30 overcome the biasing force.

31

1 The or each finger is typically pivotally coupled to
2 the housing using a pivot, such as a pivot pin, hinge
3 or the like. Optionally, a biasing means may be
4 provided to bias the fingers radially outward. The
5 biasing means may comprise a torsion spring that is
6 positioned at the pivot.

7
8 An outer face of the or each finger typically defines
9 a cone. The outer faces of the or each finger are
10 typically angled so that the cone formed thereby
11 faces in the direction of travel of the apparatus.
12 Thus, as the apparatus is moved in the direction of
13 travel, the outer faces engage an inner wall of the
14 expandable member or the like to expand the
15 expandable member.

16
17 Optionally, the outer faces may include a second
18 sloping face that is angled so that the apparatus can
19 expand the inner diameter of the tubular when moved
20 in the opposite direction to the normal direction of
21 travel. In this embodiment, there is provided a
22 double-sided cone that can be used in either
23 direction of travel to expand the expandable member.

24
25 The expandable member can be any tubular member, such
26 as casing, liner, drill pipe etc, and other such
27 downhole tubulars.

28
29 Embodiments of the present invention shall now be
30 described, by way of example only, with reference to
31 the accompanying drawings, in which:-

1 Fig. 1 is a cross-sectional elevation of a first
2 embodiment of apparatus for radially expanding
3 an expandable member;
4 Fig. 2 is a view of the apparatus of Fig. 1 in a
5 contracted configuration;
6 Fig. 3 is a cross-sectional elevation of a
7 second embodiment of apparatus for radially
8 expanding an expandable member;
9 Fig. 4 is a view of the apparatus of Fig. 3 in a
10 contracted configuration;
11 Fig. 5 is a graph showing a typical relationship
12 between an expanding diameter of the apparatus
13 of Figs 1 and 2 with the pulling force applied
14 to the apparatus;
15 Fig. 6 is a graph showing a typical relationship
16 between an expanding diameter of the apparatus
17 of Figs 3 and 4 with the pulling force applied
18 to the apparatus and/or where the apparatus of
19 Figs 1 and 2 is provided with a pre-tensioning
20 means;
21 Fig. 7a is a cross-sectional view of a third
22 embodiment of apparatus for radially expanding
23 an expandable member;
24 Fig. 7b is an enlarged view of a portion of the
25 apparatus of Fig. 7a;
26 Fig. 7c is a graph showing a relationship
27 between an expanding diameter of the apparatus
28 of Figs 7a and 7b with the pulling force applied
29 to the apparatus; and

1 Fig. 8a is a cross-sectional elevation of part
2 of a fourth embodiment of apparatus for radially
3 expanding an expandable member; and
4 Fig. 8b is an enlarged view of a portion of the
5 apparatus of Fig. 8a.

6
7 Referring to the drawings, Fig. 1 shows a part cross-
8 sectional elevation of an exemplary embodiment of
9 apparatus, generally designated 10, for expanding an
10 expandable member such as liners, casings, drill pipe
11 and other such downhole tubulars. It should be noted
12 that the terms "upper" and "lower" will be used
13 herein with reference to the orientation of the
14 apparatus 10 as shown in Fig. 1, but this is
15 arbitrary.

16
17 The expandable member may comprise any tubular, such
18 as drill pipe, liner, casing or the like and is
19 typically of a ductile material so that it can be
20 radially expanded. The radial expansion of the
21 expandable member typically causes the member to
22 undergo plastic and/or elastic deformation to
23 increase its inner and outer diameters.

24
25 Apparatus 10 includes a housing 12 that is typically
26 cylindrical, although other shapes and configurations
27 are also contemplated. Housing 12 is provided with a
28 blind bore 14.

29
30 A shaft 16 is located within the bore 14 and attached
31 to the housing 12 via a resilient member, which in

1 this embodiment comprises a spring 18, provided at
2 the (blind) lower end of the bore 14. Any member
3 that has resilient properties, i.e. it can regain its
4 original shape and configuration after being
5 stretched, compressed or otherwise deformed, can be
6 used. The purpose of the resilient member 18 is to
7 absorb an axial pulling force (represented by arrows
8 20 in Fig. 1) applied to the shaft 16 during
9 expansion, and to isolate that axial force from a
10 radial expansion force that is applied to a plurality
11 of cone segments or fingers 22, as will be described.

12

13 The biasing force of the resilient member 18 (e.g.
14 the spring) is preferably rated at a higher level
15 than the anticipated maximum pulling force or load 20
16 applied to the apparatus 10 in the axial direction.
17 Thus, in normal use, the resilient member 18 will not
18 be fully extended, provided that the maximum load 20
19 does not exceed the biasing force of the spring 18.
20 However, when the axial load 20 exceeds the biasing
21 force of the spring 18 (i.e. the anticipated maximum
22 pulling force in the axial direction overcomes the
23 biasing force of spring 18), the spring 18 extends
24 (Fig. 2), as will be described.

25

26 Shaft 16 is provided with attachment means (not
27 shown) at an upper portion 16u that is used to couple
28 the apparatus 10 to a drill string or the like. The
29 attachment means may comprise any conventional
30 coupling, such as screw threads (e.g. a pin and/or
31 box connection) or the like.

1
2 Shaft 16 is also provided with a central bore 16b for
3 the passage of fluids therethrough. Similarly,
4 housing 12 is provided with a bore 12b at the lower
5 end thereof so that fluid can pass from above to
6 below the apparatus 10, or vice versa. This
7 facilitates the circulation of fluids within the
8 borehole, both when the apparatus 10 is being run in,
9 and also whilst it is in use. Optionally, fluid
10 pressure may be used to propel the apparatus 10, as
11 will be described.

12
13 The shaft 16 is further provided with a reduced
14 diameter portion 16r that facilitates inward movement
15 of the fingers 22, as will be described.

16
17 The plurality of cone segments or fingers 22 (only
18 two shown in Fig. 1) are pivotally coupled to the
19 housing 12 around its circumference, using, for
20 example, a pivot pin 24 or the like. It is preferred
21 that the fingers 22 are capable of movement in a
22 radial direction so that they can assume either a
23 radially expanded configuration (shown in Fig. 1), or
24 a retracted configuration (shown in Fig. 2).
25 Optionally, the fingers 22 may also be capable of
26 movement in an axial direction.

27
28 In the radially expanded configuration, as shown in
29 Fig. 1, the fingers 22 are extended so that they form
30 an outer diameter that approximates the final
31 (expanded) inner diameter of the expandable member,

1 to effect radial expansion thereof. In the retracted
2 configuration shown in Fig. 2, the fingers 22 assume
3 an outer diameter that is less than the nominal
4 (unexpanded) inner diameter of the expandable member,
5 and typically less than an outer diameter of the
6 housing 12, although this is not essential. Thus,
7 when in the expanded configuration, the fingers 22
8 expand the expandable member. In the retracted
9 configuration, the fingers 22 can bypass restrictions
10 within the expandable member or restrictions that
11 protrude into the path of the apparatus 10 from, for
12 example, the surrounding formation, that would arrest
13 the travel of the apparatus 10.

14
15 A plurality of windows or slots 25 are provided in
16 the housing 12 to accommodate the radial movement of
17 the fingers 22. The windows 25 may also be
18 dimensioned to allow for movement of the fingers 22
19 in the axial direction also.

20
21 The shaft 16 is provided with an enlarged diameter
22 portion 16e that has an outer profile corresponding
23 to an inner profile of the fingers 22. In
24 particular, the outer profile of the enlarged portion
25 16e has a flat portion 16f, and a sloping portion,
26 16s. Correspondingly, the inner surface of the
27 fingers 22 has a flat portion 22f, and a sloping
28 portion 22s.

29
30 In normal use, the respective portions 16f, 22f, 16s,
31 22s engage so that the shaft 16 prevents the fingers

1 22 from moving radially inward, and can also provide
2 support to the fingers 22 during the expansion
3 process. It is preferred, but not essential, that
4 the angle of the sloping portions 16s, 22s is
5 relatively shallow. The shallow angle provides a
6 larger contact area for the compressive force applied
7 through the fingers 22 to the shaft 16 at an angle
8 perpendicular to the sloping portion 22s, as movement
9 of the fingers 22 past the obstruction will push the
10 fingers 22 radially inward. To overcome this
11 compressive force, a torsion spring or any other
12 biasing means can be used, for example at the pivots
13 24, to bias the fingers radially outward. The
14 biasing force of the torsion spring would be at least
15 equal to the normal compressive force applied to the
16 fingers 22 when an obstruction is encountered.

17

18 It should be noted that the angle of the face 16s to
19 the axis of the apparatus 10 can be adjusted to
20 provide a gearing effect. With the surface 16s at a
21 shallow angle that is close to parallel to the axis
22 of the shaft 16, the force required to move the shaft
23 16 and extend the spring 18 is high; whereas with the
24 surface 16s at a steep angle near perpendicular to
25 the axis, the shaft 16 can be induced to move and
26 extend the spring 18 under a fairly small force
27 applied through the fingers 22.

28

29 The expandable member is expanded by an outer face 26
30 of the fingers 22 that together with an upper portion
31 26u form an expansion cone made up from the

1 individual fingers 22, each tapering towards the
2 direction of travel from a widest point 28. When the
3 fingers 22 are in the radially extended position, as
4 shown in Fig. 1, the upper portions 26u of the faces
5 26 form a first expansion cone, the apex of which
6 points in the direction of travel of the apparatus
7 10. It is preferred, but not essential, that the
8 upper portions 26u of the outer faces 26 form a
9 continuous surface to expand the expandable member or
10 the like across the entire inner circumference
11 thereof.

12
13 In the Fig. 1 embodiment, each finger 22 has a lower
14 portion 26l that tapers from the widest point 28
15 radially inwards towards the other end of the
16 fingers. Thus, faces 27 on the lower portion 26l
17 form a second expansion cone that can be used to
18 expand the expandable member in the reverse direction
19 (that is the direction opposite to the normal
20 direction of travel). It should be noted that the
21 provision of the second expansion cone formed by the
22 faces 27 on the lower portion 26l is optional.

23
24 The widest point 28 is created at the junction
25 between the upper and lower outer faces 26, 27.

26
27 In use, the apparatus 10 is attached to a drill
28 string or the like using the attachment means
29 typically located at the upper end 16u of the shaft
30 16.

31

1 An expandable member that is to be located in the
2 borehole and then expanded can be positioned on top
3 of the apparatus 10. That is, the expandable member
4 can be rested on the upper face 26u of the fingers 22
5 whilst the drill string is inserted into the
6 borehole. The expandable member is then anchored
7 into place, for example using an anchoring device
8 (e.g. a packer) at the top or bottom of the
9 expandable member, depending on the direction of
10 propulsion of the apparatus 10.

11
12 The apparatus 10 is generally pulled up through the
13 expandable member using the drill string so that the
14 upper faces 26u on the fingers 22 radially expands
15 the inner surface of the expandable member. In this
16 case, the expandable member would typically be
17 anchored at a lower end thereof. The expandable
18 member is preferably expanded sufficiently so that
19 the outer surface thereof presses against the
20 formation of the borehole, or the pre-installed
21 portion of expandable member, casing etc.

22
23 Referring to Fig. 2, if during the expansion process,
24 the apparatus 10 becomes stuck, for example due to a
25 solid protrusion on or in the expandable member into
26 the path of the apparatus 10, or a solid protrusion
27 in the surrounding formation that extends into the
28 path of the apparatus 10, the spring 18 extends in
29 the axial direction because the force that is used to
30 pull the apparatus 10 through the expandable member
31 increases, the apparatus 10 stops moving at the

1 protrusion, and the increased force will be greater
2 than the force required to overcome the biasing force
3 of the spring 18. As the spring 18 expands, the
4 shaft 16 and in particular the enlarged portion 16e
5 is moved upwardly in the axial direction as shown in
6 Fig. 2.

7
8 As shaft 16 moves upwards and the housing 12 is
9 arrested at the protrusion, the fingers 22 are no
10 longer supported by the enlarged diameter portion 16e
11 and can move radially inward. This inward movement
12 of at least one of the fingers 22 can allow the
13 apparatus 10 to bypass the restriction. This process
14 can be aided if the fingers 22 are capable of some
15 axial movement in the opposite direction to the
16 movement of the shaft 16. The axial movement can be
17 aided by providing elongated slots that extend in the
18 axial direction at the pivots 24. When the fingers
19 22 encounter a restriction at the expansion point 28,
20 the axial pulling force 20 will tend to pull the
21 apparatus 10 upwardly. If the pivot pins 24 are
22 located in axial slots, the fingers 22 can move
23 axially downwards in the slots relative to the
24 housing 12, further separating the enlarged diameter
25 portion 16e and the fingers 22 and allowing the
26 fingers 22 to move radially inward.

27

28 As the protrusion is passed, the spring 18 contracts
29 because it has a higher biasing force than the normal
30 pulling force 20 applied to the apparatus 10, and the
31 fingers 22 move radially outward to the position

1 shown in Fig. 1 due to the engagement of the enlarged
2 diameter portion 16e with the fingers 22, and/or the
3 biasing force applied to the fingers 22 (e.g. at the
4 pivot pins 24).

5
6 Thus, as the fingers 22 can contract by moving
7 radially inwards (and optionally axially), the
8 apparatus 10 does not become permanently stuck,
9 thereby obviating having to retrieve the apparatus 10
10 from the borehole. This provides an advantage in
11 that no rig time is lost in having to perform a
12 fishing operation to retrieve the stuck expander
13 device. Also, the apparatus 10 resets itself back
14 into expansion mode due to the biasing force of the
15 spring 18. Thus, it can bypass any number of
16 restrictions within the borehole without having to be
17 retrieved therefrom and manually reset.

18
19 It should be noted that reversing the direction of
20 travel of the apparatus 10 could aid in freeing it,
21 as the fingers 22 will be pushed radially inward due
22 to contact with the restriction.

23
24 Hydraulic or other types of fluid pressure may be
25 used to propel the apparatus 10. In this particular
26 embodiment, the apparatus 10 would be turned upside
27 down with respect to the orientation shown in Figs 1
28 and 2. Fluid pressure can then be applied to the
29 apparatus 10, at least a portion of which preferably
30 acts directly on the end of shaft 16, typically via a
31 throughbore 12b in housing 12. The bore 16b through

1 the shaft 16 is generally not required for this
2 particular embodiment. However, the bore 16b can be
3 provided with a restriction (e.g. a blind bore) so
4 that fluid pressure in the bore 16b can be contained
5 to aid movement of the shaft 16.

6
7 It will be appreciated that bore 12b can be made
8 larger or smaller to adjust the pressure that is
9 applied to the end of the shaft 16. The end of the
10 shaft 16 could be provided with a flared end
11 (optionally with seals) that engages bore 14 of the
12 housing 12.

13
14 Fluid pressure would be applied to housing 12, and a
15 portion of this pressure would act directly on the
16 shaft 16 via bore 12b. The contact between the upper
17 faces 26u (which would be lower faces with the
18 apparatus 10 turned upside down) with the expandable
19 member that is to be expanded would create a seal for
20 the fluid pressure. The apparatus 10 could thus be
21 used to expand the expandable member from the top
22 down. This is advantageous, as no rig would be
23 required to push or pull the apparatus 10 (only fluid
24 pressure), but the apparatus 10 would generally need
25 to be retrieved from the borehole once the expandable
26 member has been expanded.

27
28 As the apparatus 10 is propelled through the
29 expandable member using fluid pressure, the upper
30 faces 26u of the fingers 22 form an expansion cone
31 that will radially expand the expandable member. As

1 with the previous embodiment, if during the expansion
2 process the apparatus 10 becomes stuck, the spring 18
3 extends in the axial direction because the fluid
4 pressure applied to the shaft 16 increases, but the
5 apparatus 10 stops moving at the protrusion, and the
6 increased force will be greater than the force
7 required to overcome the biasing force of the spring
8 18. The spring 18 expands, and the shaft 16, in
9 particular the enlarged diameter portion 16e, is
10 moved downwardly in the axial direction. The
11 downward movement of shaft 16 allows the fingers 22
12 to move inward as they are no longer supported by the
13 enlarged diameter portion 16e. This inward movement
14 of at least one of the fingers 22 can allow the
15 apparatus 10 to bypass the restriction.

16

17 Where the bore 16b is provided with a restriction,
18 the build up of fluid pressure caused by the arrest
19 in the travel of the apparatus 10 will aid in moving
20 the shaft 16 against the bias force of spring 18, so
21 that the enlarged portion 16e moves out of contact
22 with the fingers 22, allowing one or more fingers 22
23 to move radially inward.

24

25 As the protrusion is passed, the spring 18 contracts
26 because it has a higher biasing force than the force
27 of the fluid pressure applied to the apparatus 10,
28 and the fingers 22 move radially outward due to the
29 engagement of the enlarged diameter portion 16e with
30 the fingers 22, and/or the biasing force applied to
31 the fingers 22 (e.g. at the pivot pins 24).

1
2 Alternatively, the shaft 16 in this embodiment could
3 be attached to the housing 12 above the level of the
4 fingers 22, for example using a spring. The spring
5 would typically be a compressive spring where in its
6 normal state the spring is extended, but can be
7 compressed.
8
9 As fluid pressure is applied to the bottom of shaft
10 16 and/or the housing 12, the apparatus is moved
11 through the expandable member to radially expand the
12 expandable member (typically using upper faces 26u).
13 When the apparatus meets a restriction in its path,
14 the travel of the apparatus is arrested at which
15 point the fluid pressure acts on shaft 16 thereby
16 compressing the spring. The compression of the
17 spring allows the shaft 16 to move axially and thus
18 the enlarged portion 16e moves out of contact with
19 the fingers 22 allowing them to move radially inwards
20 and thus by-pass the restriction. Once the
21 restriction is passed, the spring extends to its
22 normal configuration and expansion of the expandable
23 member continues.
24
25 It will be appreciated that the force that normally
26 biases the spring to move the shaft 16 away from the
27 housing can be selected to provide a pre-tensioning
28 means, as described below.
29
30 It should be noted that as the fingers 22 are
31 independently attached to the housing 12, partial

1 collapse of the cone formed thereby is possible.
2 This may result in, for example, an elliptical shape
3 at the widest point 28.

4

5 Figs 3 and 4 show an alternative embodiment of
6 apparatus according to the present invention,
7 generally designated 100. Apparatus 100 is similar
8 to apparatus 10 (Figs 1 and 2) and includes a housing
9 112 (shown in part cross-section) that is typically
10 cylindrical, although other shapes and configurations
11 are also contemplated. The housing 112 is provided
12 with an internal cavity or bore 114 in which a shaft
13 116 is partially located.

14

15 An upper portion 116u of the shaft 116 is typically
16 provided with conventional coupling means (e.g. screw
17 threads) so that the apparatus 100 can be coupled to
18 a drill string, coiled tubing string, wireline or the
19 like. Thus, the apparatus 100 can be pulled through
20 an expandable member 150 that is to be expanded.

21

22 Shaft 116 is capable of longitudinal movement within
23 the cavity 114 relative to housing 112 and is biased
24 to the position shown in Fig. 3 by a resilient
25 member, which in this embodiment comprises a spring
26 118. Spring 118 is located below the housing 112,
27 typically between a lower face 112l of the housing
28 112 and a lower face 116l of the shaft 116. It
29 should be noted that spring 118 is merely exemplary,
30 and any member that has resilient properties, i.e. it
31 can regain its original shape and configuration after

1 being stretched, compressed or otherwise deformed,
2 can be used. In the embodiment shown in Figs 3 and
3 4, the spring 118 is typically normally extended.

4
5 As with the previous embodiment, the purpose of the
6 spring 118 is to absorb an axial pulling or
7 propulsive force applied to the shaft 116 during the
8 radial expansion process (as described below), and to
9 isolate that axial pulling or propulsive force from a
10 radial expansion force that is applied to a plurality
11 of cone segments or fingers 122, as will be
12 described.

13
14 The biasing force of the spring 118 is preferably
15 rated at a higher level than the anticipated maximum
16 pulling or propulsive force applied to the apparatus
17 100 in the axial direction. Thus, in normal use, the
18 spring 118 is typically fully extended, provided that
19 the maximum pulling or propulsive force does not
20 exceed the biasing force of the spring 118. However,
21 when the axial pulling or propulsive force exceeds
22 the biasing force of the spring 118 (i.e. the
23 anticipated maximum pulling or pushing force in the
24 axial direction overcomes the biasing force of spring
25 118), the spring 118 contracts (Fig. 4), as will be
26 described.

27
28 The embodiment shown in Figs 3 and 4 can be propelled
29 through the casing using hydraulic or other fluid
30 pressure. An optional stop 120 is provided that is
31 engageable with a lower end of the shaft 116. Fluid

1 acts on a lower surface 1201 of the stop 120 and thus
2 propels the apparatus 100 upwardly, providing that
3 the force of fluid pressure is sufficient. The stop
4 120 can be provided with sealing means that seal
5 between outer surfaces 1200 of the stop 120 and the
6 inner surface of the expandable member 150 that is to
7 be radially expanded.

8
9 In this particular embodiment, the shaft 116 and the
10 optional stop 120 are not provided with throughbores
11 (unlike the previous embodiment) although they may be
12 if required. The throughbores could facilitate the
13 circulation of fluids within the borehole, both when
14 the apparatus 100 is being run in, and also whilst it
15 is in use.

16
17 The plurality of cone segments or fingers 122 (only
18 one shown in Fig. 1) are pivotally coupled to the
19 housing 112 around its circumference, using, for
20 example, a pivot pin 124 or the like. It is
21 preferred that the fingers 122 are capable of
22 movement in a radial direction so that they can
23 assume either a radially expanded configuration
24 (shown in Fig. 3), or a retracted configuration
25 (shown in Fig. 4). Optionally, the fingers 122 may
26 also be capable of movement in an axial direction.

27
28 In the radially expanded configuration, as shown in
29 Fig. 3, the fingers 122 are extended so that they
30 form an outer diameter that approximates the final
31 (expanded) inner diameter of the expandable member

1 150, casing etc to effect radial expansion thereof.
2 In the retracted configuration shown in Fig. 4, the
3 fingers 122 assume an outer diameter that is less
4 than the nominal (unexpanded) inner diameter of the
5 expandable member 150, and typically less than an
6 outer diameter of the housing 112, although this is
7 not essential. Thus, when in the expanded
8 configuration, the fingers 122 expand the expandable
9 member 150. In the retracted configuration, the
10 fingers 122 can bypass restrictions within the
11 expandable member 150 or restrictions that protrude
12 into the path of the apparatus 100 from, for example,
13 the surrounding formation, that would arrest the
14 travel of the apparatus 100.

15
16 A plurality of windows or slots 125 are provided in
17 the housing 112 to accommodate the radial movement of
18 the fingers 122. The windows 125 may also be
19 dimensioned to allow for movement of the fingers 122
20 in the axial direction.

21
22 As with the previous embodiment, shaft 116 is
23 provided with an enlarged diameter portion 116e. The
24 enlarged diameter portion 116e has a flat portion
25 116f, and a sloping portion 116s. In this
26 embodiment, the fingers 122 are provided with a
27 rounded inner surface 122r that typically engages the
28 flat surface 116f of the enlarged portion 116e during
29 normal use (as shown in Fig. 3). Fingers 122 may
30 have a similar inner profile to fingers 22.

31

1 In normal use, the rounded inner surface 122r engages
2 the flat surface 116f so that the shaft 116 prevents
3 the fingers 122 from moving radially inward, and can
4 also provide support to the fingers 122 during the
5 expansion process. As with the previous embodiment,
6 a torsion spring or any other biasing means can be
7 used, for example at the pivots 124, to bias the
8 fingers 122 radially outward. The biasing force of
9 the torsion spring would be at least equal to the
10 normal compressive force applied to the fingers 122
11 when an obstruction is encountered.
12

13 The expandable member 150 is expanded by an outer
14 face 126 of the fingers 122 that together with an
15 upper portion 126u form an expansion cone made up
16 from the individual fingers 122, each tapering
17 towards the direction of travel from a widest point
18 128. When the fingers 122 are in the radially
19 extended position, as shown in Fig. 3, the upper
20 portions 126u of the faces 126 form a first expansion
21 cone, the apex of which points in the direction of
22 travel of the apparatus 100. It is preferred, but
23 not essential, that the upper portions 126u of the
24 outer faces 126 form a continuous surface to expand
25 the expandable member 150 or the like across the
26 entire inner circumference thereof.
27

28 In the Fig. 3 embodiment, each finger 122 has a lower
29 portion 126l that tapers from the widest point 128
30 radially inwards towards the other end of the
31 fingers. Thus, faces 127 on the lower portion 126l

1 form a second expansion cone that can be used to
2 expand the expandable member 150 in the reverse
3 direction (that is the direction opposite to the
4 normal direction of travel). It should be noted that
5 the provision of the second expansion cone formed by
6 the faces 127 on the lower portion 126l is optional.

7
8 The widest point 128 is created at the junction
9 between the upper and lower outer faces 126, 127.

10

11 In use, the apparatus 100 may be attached to a drill
12 string, coiled tubing string, wireline or the like.
13 The expandable member 150 that is to be located in
14 the borehole and then expanded can be positioned on
15 top of the apparatus 100. That is, the expandable
16 member 150 can be rested on the upper face 126u of
17 the fingers 122 whilst the expandable member 150 or
18 the like is inserted into the borehole. The
19 expandable member 150 is then anchored into place,
20 for example using an anchoring device (e.g. a packer)
21 at the top or bottom of the expandable member 150,
22 depending on the direction of motion of the apparatus
23 100.

24

25 The apparatus 100 is pulled or propelled upwardly
26 through the expandable member 150 ("upwardly" being
27 arbitrary and with respect to the orientation of the
28 apparatus 100 in Figs 3 and 4) using a drill string
29 or the like to pull the apparatus 100, or by applying
30 fluid pressure to the lower surface 120l of the stop
31 120. The upper portions 126u on the fingers 122

1 radially expand the inner surface of the expandable
2 member 150 as the apparatus 100 is pulled or
3 propelled through the casing. In this case, the
4 expandable member 150 would typically be anchored at
5 or near a lower end thereof. The expandable member
6 150 is preferably expanded sufficiently so that the
7 outer surface of the expandable member 150 presses
8 against the formation of the borehole, or the pre-
9 installed portion of liner, casing etc.

10

11 Referring to Fig. 4, if during the expansion process,
12 the apparatus 100 becomes stuck, for example due to a
13 solid protrusion on or in the expandable member 150
14 in the path of the apparatus 100, or a solid
15 protrusion in the surrounding formation that extends
16 into the path of the apparatus 100, the spring 118
17 contracts in the axial direction because the pulling
18 or fluid force that is used to pull or propel the
19 apparatus 100 through the expandable member 150
20 increases, the apparatus 100 stops moving at the
21 protrusion, and the increased force will be greater
22 than the force required to overcome the biasing force
23 of the spring 118. As the spring 118 contracts, the
24 shaft 116 and in particular the enlarged portion 116e
25 is moved upwardly in the axial direction as shown in
26 Fig. 4.

27

28 As shaft 116 moves upwards and the housing 112 is
29 arrested at the protrusion, the fingers 122 are no
30 longer supported by the enlarged diameter portion
31 116e and can move radially inward. This inward

1 movement of at least one of the fingers 122 can allow
2 the apparatus 100 to bypass the restriction. This
3 process can be aided if the fingers 122 are capable
4 of some axial movement in the opposite direction to
5 the movement of the shaft 116. The axial movement
6 can be aided by providing elongated slots that extend
7 in the axial direction at the pivots 124. When the
8 fingers 122 encounter a restriction at the widest
9 point 128, the fluid propulsion will tend to push the
10 apparatus 100 upwardly. If the pivot pins 124 are
11 located in axial slots, the fingers 122 can move
12 axially downwards in the slots relative to the
13 housing 112, further separating the enlarged diameter
14 portion 116e and the fingers 122 and allowing the
15 fingers 122 to move radially inward.

16
17 As the protrusion is passed, the spring 118 expands
18 because it has a higher biasing force than the normal
19 pulling or propulsive force applied to the apparatus
20 100, and the fingers 122 move radially outward to the
21 position shown in Fig. 3 due to the engagement of the
22 enlarged diameter portion 116e with the fingers 122,
23 and/or the biasing force applied to the fingers 122
24 (e.g. at the pivot pins 124).

25
26 Thus, as the fingers 122 can contract by moving
27 radially inwards (and optionally axially), the
28 apparatus 100 does not become permanently stuck,
29 thereby obviating having to retrieve the apparatus
30 100 from the borehole. This provides an advantage in
31 that no rig time is lost in having to perform a

1 fishing operation to retrieve the stuck expander
2 device. Also, the apparatus 100 resets itself back
3 into expansion mode due to the biasing force of the
4 spring 118. Thus, it can bypass any number of
5 restrictions within the borehole without having to be
6 retrieved therefrom and manually reset.

7
8 It should be noted that as the fingers 122 are
9 independently attached to the housing 112, partial
10 collapse of the cone formed thereby is possible.
11 This may result in, for example, an elliptical shape
12 at the widest point 128.

13
14 In this particular embodiment, setting weight on the
15 shaft 116 from the drill string, coiled tubing string
16 etc from above can aid in resetting the apparatus 100
17 and thus open up the fingers 122 to form the
18 expansion cone.

19
20 The axial pulling force, represented by F_e in Figs 3
21 to 6, is typically directly related to the diameter
22 of the apparatus 100 at the widest point 128 of the
23 fingers 122. Referring to Fig. 5, there is shown the
24 general relationship between the diameter at the
25 widest point (represented in Figs 5 and 6 as $\phi 3$) and
26 the axial pulling force F_e . As can be seen from Fig.
27 5, the diameter at the widest point reduces linearly
28 as the pulling force F_e increases.

29
30 However, it is preferred that the apparatus 100 is
31 provided with a means that prevents the fingers 122

1 from moving inward until a given value of pulling
2 force F_e is achieved or preferably exceeded.

3
4 Fig. 6 shows a pre-tensioning force F_c that can be
5 applied to the apparatus 100, where F_c is typically
6 greater than or equal to F_e . Thus, the pre-
7 tensioning allows for a certain amount of travel of
8 the shaft 116 in the axial direction before the
9 fingers 122 can move inwards.

10
11 With the embodiment shown in Figs 3 and 4, a distance
12 a is provided between the nominal engagement point of
13 the rounded face 122r with the enlarged diameter
14 portion 116e and the point where the enlarged
15 diameter begins to reduce down to the nominal
16 diameter of the shaft 116. The distance a
17 facilitates normal force variations so that the
18 fingers 122 do not collapse unless the pulling force
19 or build-up of fluid pressure on the stop 120 is
20 sufficient to move the shaft 116 upwards by a
21 distance that exceeds distance a. Thus, the distance
22 a effectively provides a pre-tensioning force as the
23 shaft 116 can tolerate force variations until it is
24 pulled upwards by a distance that exceeds distance a.

25
26 It will be noted that there is a relationship between
27 the slope β and the length c (Figs 3 and 4) and these
28 are connected by the change in outer diameter of the
29 upper expansion cone formed by faces 126. The force
30 required to restore the expansion cone to its
31 original configuration where it expands the

1 expandable member 150 decreases as the slope β
2 increases. This is similar to the gearing effect of
3 Figs 1 and 2.

4
5 Fig. 7 shows a further alternative embodiment of
6 apparatus according to the present invention. In the
7 embodiment shown in Fig. 7, each finger 222 has a
8 fixed piston 280 associated with it. The fixed
9 piston 280 has an internal bore 280b that allows
10 pressurised fluid from a reservoir, generally
11 designated 282, located within the shaft 216 to flow
12 through the piston 280 and collect in a chamber 284
13 behind the finger 222.

14
15 The reservoir 282 includes a fluid-filled chamber 286
16 that has a piston 288 located above the chamber 286,
17 and a damping spring 290 above the piston 288. The
18 chamber 286 communicates with the chambers 284 behind
19 the fingers 222 via connecting channels 292.

20
21 In the Fig. 7 embodiment, the apparatus 200 is moved
22 upwards by applying a pulling force F_a to the shaft
23 216 as before. If the apparatus 200 encounters a
24 restriction or resistance to upward movement, the
25 fingers 222 that are mounted on pivots 224 move
26 inwards. The inward movement of the fingers 222 acts
27 on the fluid chamber 284 causing the fluid therein to
28 be pushed inwardly into the channels 292, thus
29 forming a radial piston. This inward movement causes
30 the fluid pressure in the channels 292 and chamber
31 286 to increase and the damping spring 290 absorbs

1 the increase in pressure, allowing the fingers 222 to
2 move inwards so that the restriction can be passed.
3 The damping spring 290 can be any conventional
4 spring, such as gas, mechanical etc. Once the
5 restriction has passed, the fluid pressure reduces
6 and the bias force of the damping spring 290 causes
7 the fingers 222 to expand to their nominal expansion
8 diameter by forcing fluid out of the chamber 288 into
9 the channels 292 and into the chamber 284 behind the
10 fingers 222.

11
12 It is possible with the embodiment shown in Fig. 7 to
13 control the fluid pressure in the chambers 286 and
14 284 from the surface. Thus, the apparatus 200 can be
15 run into an expandable member that is to be expanded
16 in an unexpanded configuration. Once the apparatus
17 200 has reached its intended location within the pre-
18 installed casing, liner etc., fluid pressure in the
19 apparatus 200 can be increased causing the fingers
20 222 to assume their expanded position and the
21 apparatus 200 can be pulled upwards to radially
22 expand the expandable member.

23
24 As with the previous embodiment, the biasing force
25 (f_{spring}) of the spring 290 can be chosen so that the
26 fingers 222 remain extended until a predetermined
27 pulling force F_e is exceeded (see Figs 7b and 7c).
28 Thus, the fingers 222 will not fully collapse until
29 the biasing force f_{spring} provided by the spring 290 is
30 overcome. This will allow for small variations in

1 the movement of the fingers 222 during normal use
2 without the fingers collapsing.

3
4 Fig. 8 shows a further alternative embodiment of
5 apparatus according to the present invention. The
6 apparatus, generally designated 300, includes a
7 plurality of blades 302 that are pivotally connected
8 to a body 301, typically via pins 306. Referring to
9 Fig. 8b, each blade 302a overlaps the previous blade
10 302b and an outer surface of the blades 302 typically
11 forms an expansion cone in use. It is preferred that
12 each blade 302 is pivotally mounted independently of
13 one another. The blades 302 may be restrained in the
14 amount of outward pivotal movement by a restrainer
15 303 that limits the outward movement of the blade 302
16 by engaging one end thereof. The pivot pins 306 are
17 typically provided at or near a leading edge of the
18 apparatus 300.

19
20 An inflatable element 304, such as a packer, is
21 located under the blades 302, as shown in Fig. 8a.
22 The inflatable element 304 is coupled to a hydraulic
23 absorber, generally designated 308. The hydraulic
24 absorber 308 includes an oil reservoir 310 that is in
25 fluid communication with the inflatable element 304.
26 A floating piston 312 is located beside the oil
27 reservoir 310, the piston 312 being capable of axial
28 movement within the hydraulic absorber 308. A gas
29 accumulator 314 is located beside the floating piston
30 312 and is typically filled with a gas.

31

1 In use, the inflatable element 304 is pressurised to
2 a constant pressure that is required to move the
3 blades 302 outwards to expand the expandable member
4 etc. The compressibility of the gas in the gas
5 accumulator 314 and the incompressibility of the oil
6 in the oil reservoir 310 gives a spring effect where
7 the radial or reactive force applied to the blades
8 302 from the expansion process applies a collapsing
9 force to the inflatable element 304. The increase in
10 pressure in the inflatable element 304 causes an
11 increase in pressure in the oil reservoir 310 and the
12 oil acts against the floating piston 312, forcing it
13 into the gas accumulator 314 (as the gas therein is
14 compressible). The movement of the piston 312 allows
15 the blade(s) 302 to move inward(s) and thus the
16 restriction can be passed.

17
18 The pressure within the system is typically kept
19 constant, and thus when the restriction has been
20 passed, the pressure in the inflatable element 304
21 returns to its original value, as the pressure in the
22 oil reservoir 310 reduces, allowing the gas in the
23 accumulator 314 to expand and the piston 312 moves
24 back to its original position, forcing oil into the
25 inflatable element 304.

26
27 The gas accumulator 314 could be pressurised at the
28 surface using a gas line for example, or downhole
29 using a system that is similar to the Baker Model E-4
30 Wireline Pressure Setting Assembly (Product Number
31 437-02). In this embodiment, an electric current is

1 used and transmitted through electric wireline, to
2 ignite a power charge in a setting assembly. The
3 setting assembly is slow-burning charge that releases
4 a gas as it burns, thus building up pressure in the
5 gas accumulator 314. Thus, the apparatus 300 can be
6 inserted through the expandable member that is to be
7 expanded in an unexpanded configuration, and then the
8 inflatable element 304 expanded downhole by igniting
9 the first charge that in turn ignites the power
10 charge to build up the pressure in the gas
11 accumulator 314. The gas pressure would then act on
12 the piston 312, compressing the oil in the reservoir
13 310 causing some of the oil to be transferred to the
14 inflatable element 304 thus pivoting the blades 302
15 outwardly, as shown in Fig. 8a to radially expand the
16 expandable member etc.

17
18 Embodiments of the present invention provide numerous
19 advantages over prior art expander devices, such as
20 the ability to bypass restrictions without becoming
21 arrested. In certain embodiments, the fingers or
22 blades that make up the expansion cone are capable of
23 collapsing inwards so that the restriction can be
24 passed. Thereafter, the fingers or blades are moved
25 back to their expanded configuration so that the
26 expansion process can continue.

27
28 Modifications and improvements may be made to the
29 foregoing without departing from the scope of the
30 present invention.

1 CLAIMS

2

3 1. Apparatus for expanding an expandable member,
4 the apparatus comprising a first member, one or more
5 radially movable portions, a second member, and
6 force isolating means acting between the first and
7 second members.

8

9 2. Apparatus according to claim 1, wherein the
10 first member comprises a housing with a blind bore.

11

12 3. Apparatus according to either preceding claim,
13 wherein the second member comprises a shaft having a
14 cone that bears against the radially movable
15 portions.

16

17 4. Apparatus according to claim 3, wherein the
18 shaft and cone can move axially with respect to the
19 first member in and out of engagement with the
20 radially movable portions.

21

22 5. Apparatus according to any preceding claim,
23 wherein the radially movable portions are coupled to
24 the first member so that they can move in a radial
25 and/or axial direction.

26

27 6. Apparatus according to any one of claims 3 to
28 5, wherein the force isolating means comprises a
29 spring.

30

31 7. Apparatus according to claim 6, wherein the
32 radially movable portions are held in a radially

1 expanded position by the cone on the second member
2 moving axially with respect to the first member to a
3 first position in which the spring is contracted.
4

5 8. Apparatus according to claim 7, wherein the
6 second member can move axially under an axial
7 pulling force, and the cone can move to a second
8 position that allows the radially movable portions
9 to move radially inward to bypass a restriction.
10

11 9. Apparatus according to claim 7 or claim 8,
12 wherein as the restriction is passed, the axial
13 pulling force drops below a biasing force of the
14 spring so that the spring contracts, and the cone
15 moves into engagement with the radially movable
16 portions causing them to move radially outward to
17 the radially expanded position.
18

19 10. Apparatus according to any one of claims 7 to
20 9, wherein the engagement of the radially movable
21 portions with the restriction can cause them to move
22 inwards against the cone thereby moving it to the
23 second position in which the spring is extended.
24

25 11. Apparatus according to any preceding claim,
26 wherein the radially movable portions are pivotally
27 coupled to the first member.
28

29 12. Apparatus according to any preceding claim,
30 wherein an outer face of the radially movable
31 portions defines a cone.
32

1 13. Apparatus for expanding an expandable member,
2 the apparatus comprising a body, one or more
3 radially movable portions, and force isolating means
4 acting between the body and the or each radially
5 moveable portion.

6

7 14. Apparatus according to claim 13, wherein the
8 force isolating means provides a biasing force to
9 the or each radially moveable portion.

10

11 15. Apparatus according to claim 14, wherein a
12 force required to move the or each radially moveable
13 portion inwards is greater than the biasing force of
14 the force isolating means.

15

16 16. Apparatus according to claim 14 or claim 15,
17 wherein a radial position of the or each radially
18 movable portion is at least partially controlled by
19 the biasing force of the force isolating means.

20

21 17. Apparatus according to any one of claims 14 to
22 16, wherein force applied to the body can be
23 isolated from the or each radially moveable portion
24 by the force isolating means.

25

26 18. Apparatus according to any one of claims 13 to
27 17, wherein the force isolating means comprises a
28 resilient member that allows relative movement
29 between the body and the or each radially moveable
30 portion.

31

1 19. Apparatus according to claim 18, wherein the
2 relative movement between the body and the or each
3 radially moveable portion is in an axial direction.
4

5 20. Apparatus according to claim 18 or claim 19,
6 wherein the resilient member has a biasing force
7 that is greater than a maximum load that will be
8 applied to the apparatus.
9

10 21. Apparatus according to any one of claims 13 to
11 17, wherein the force isolating means includes a
12 fluid chamber that is in communication with the or
13 each radially moveable portion, the fluid chamber
14 being in fluid communication with a spring means.
15

16 22. Apparatus according to claim 21, wherein the
17 spring means comprises a first chamber, a floating
18 piston in communication with the first chamber, and
19 a second chamber in communication with the piston.
20

21 23. Apparatus according to claim 22, wherein the
22 first chamber contains fluid and is in fluid
23 communication with the fluid chamber that is in
24 communication with the or each radially moveable
25 portion, and the second chamber includes a spring.
26

27 24. Apparatus according to claim 23, wherein as the
28 radially moveable portions are forced inward due to
29 a restriction, they act on the fluid in the fluid
30 chamber, forcing the fluid into the first chamber,
31 wherein the displacement of fluid causes the
32 floating piston to compress the spring in the second

1 chamber and this allows the radially moveable
2 portions to move inwards, thus passing the
3 restriction.

4

5 25. Apparatus according to claim 24, wherein once
6 the restriction has been passed, the spring extends
7 forcing fluid in the first chamber to be transferred
8 to the fluid chambers, thus forcing the radially
9 moveable portions outwards.

10

11 26. Apparatus according to any one of claims 13 to
12 17, wherein the force isolating means comprises a
13 hydraulic spring.

14

15 27. Apparatus according to claim 26, wherein the
16 hydraulic spring includes an inflatable element that
17 is in fluid communication with a fluid chamber.

18

19 28. Apparatus according to claim 27, wherein the
20 fluid chamber is filled with a fluid that is
21 incompressible.

22

23 29. Apparatus according to claim 27 or claim 28,
24 wherein the fluid in the fluid chamber acts on a
25 floating piston that is located in a second chamber.

26

27 30. Apparatus according to claim 29, wherein the
28 second chamber is filled with a gas.

29

30 31. Apparatus according to claim 29 or claim 30,
31 wherein as the radially moveable portions are forced
32 inwards due to a restriction, they act on the fluid

1 in the inflatable element, forcing fluid into the
2 fluid chamber, and the displacement of fluid into
3 the fluid chamber acts on the piston, causing it to
4 compress the fluid in the second chamber.

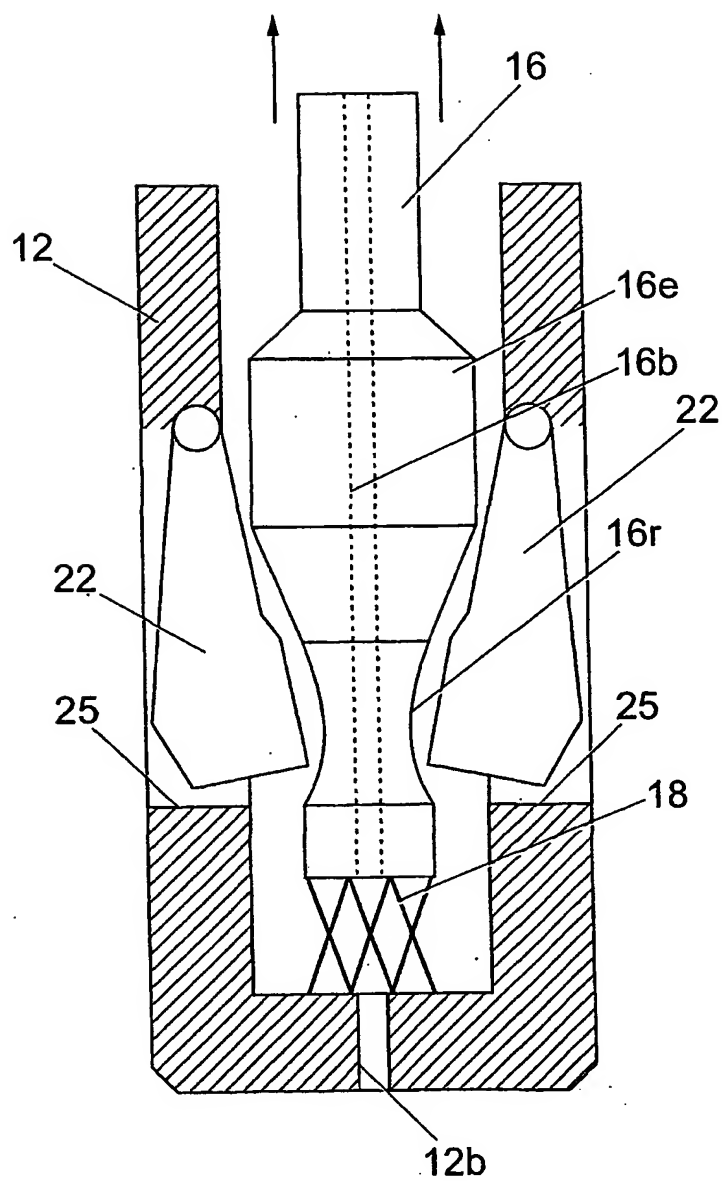
5
6 32. Apparatus according to claim 31, wherein once
7 the restriction has been passed, the fluid in the
8 second chamber expands, forcing the piston to act on
9 the fluid in the fluid chamber, the fluid being
10 transferred to the inflatable element, thus forcing
11 the radially moveable portions outwards.

12
13 33. Apparatus according to any one of claims 13 to
14 32, wherein the or each radially moveable portion is
15 pivotably mounted to the body.

16
17 34. Apparatus according to any one of claims 13 to
18 33, wherein the or each radially moveable portion
19 comprises one or more fingers.

20
21 35. Apparatus according to claim 34, wherein an
22 outer face of the or each finger defines a cone.

2/7

*Fig. 2*

SUBSTITUTE SHEET (RULE 26)

3 / 7

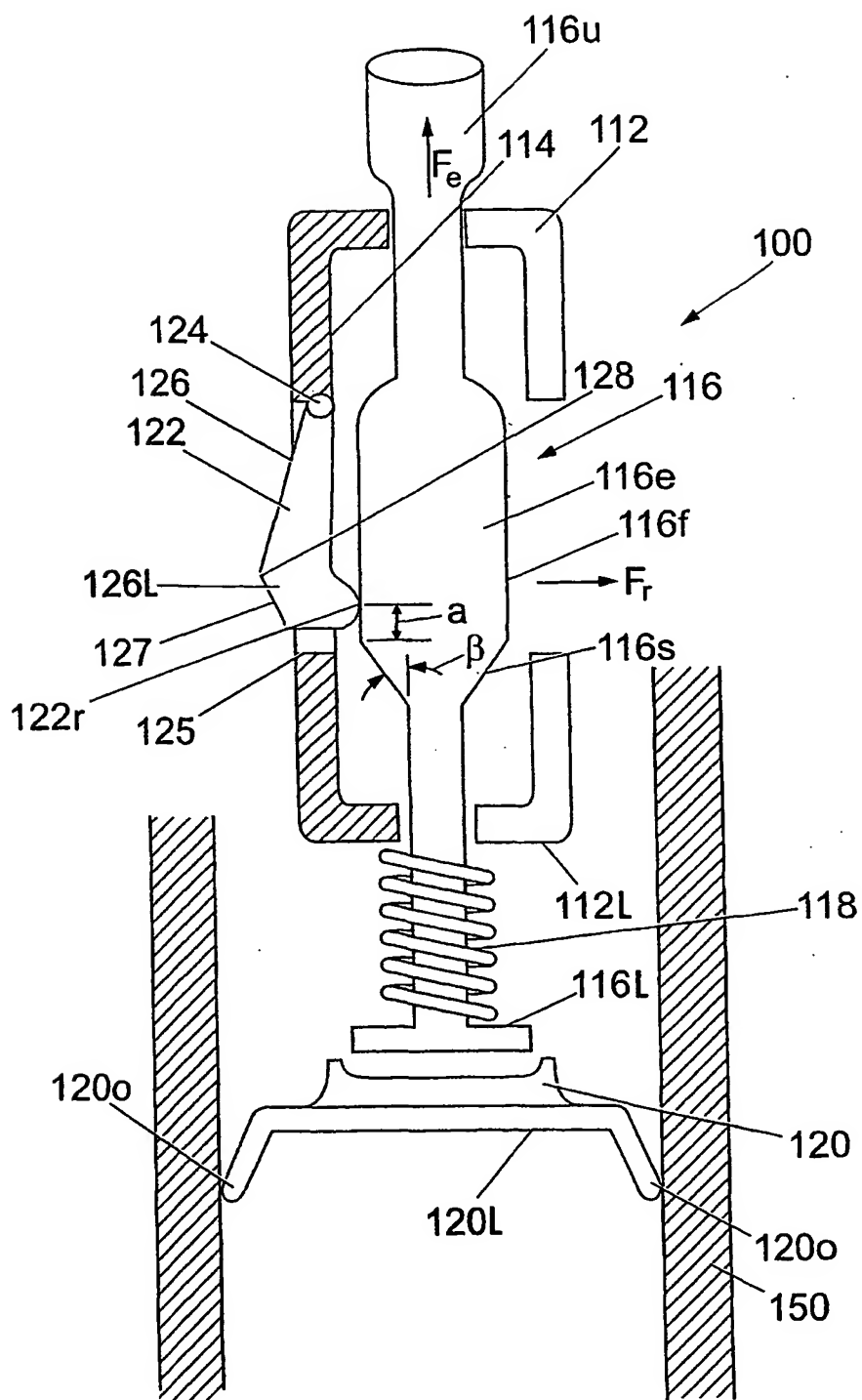


Fig. 3

SUBSTITUTE SHEET (RULE 26)

4 / 7

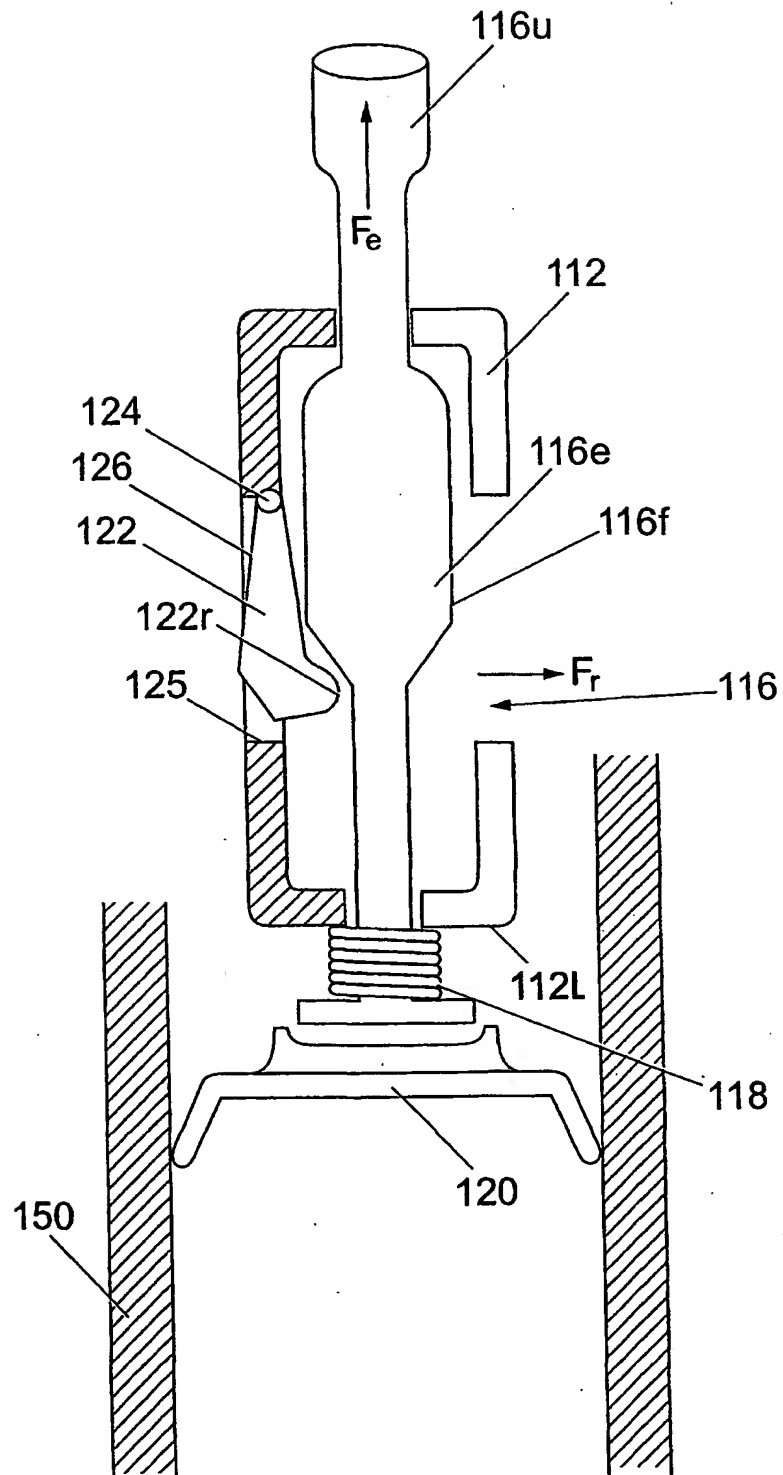
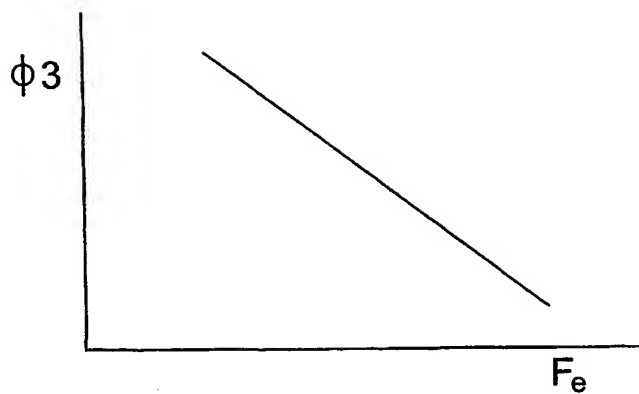
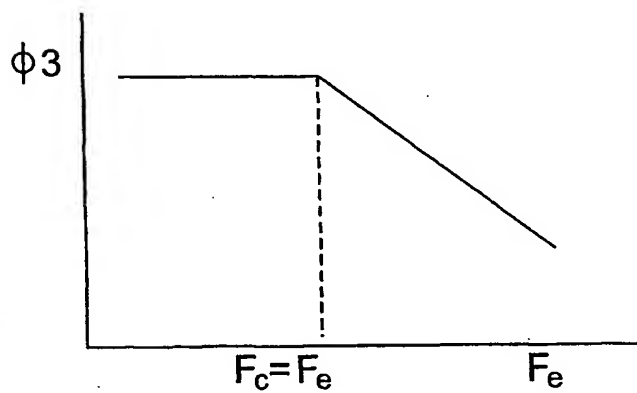


Fig. 4

SUBSTITUTE SHEET (RULE 26)

5/7

*Fig. 5**Fig. 6*

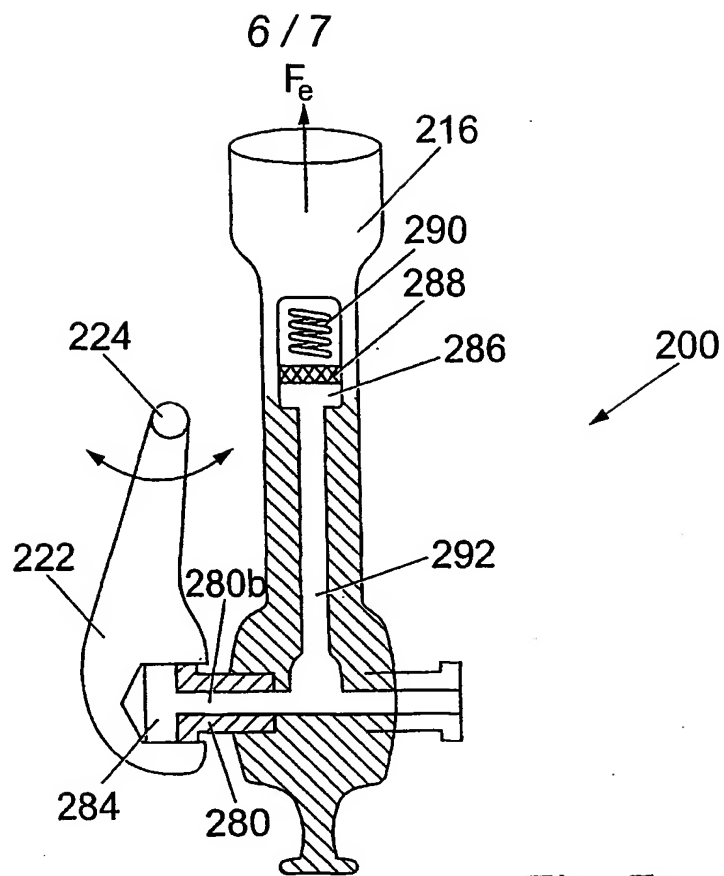


Fig. 7a

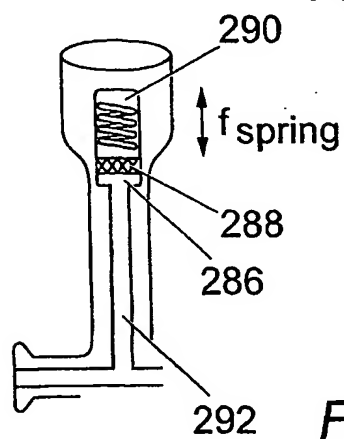


Fig. 7b

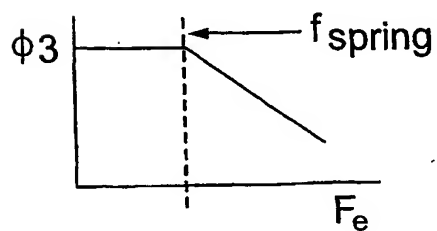
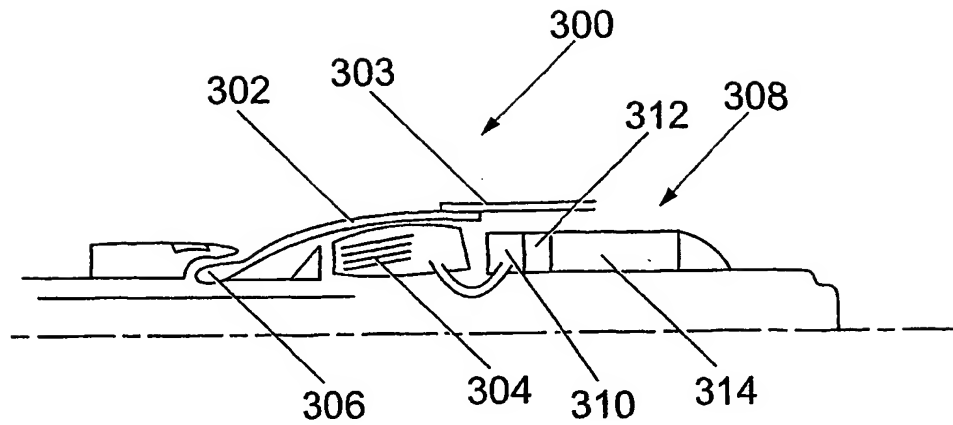
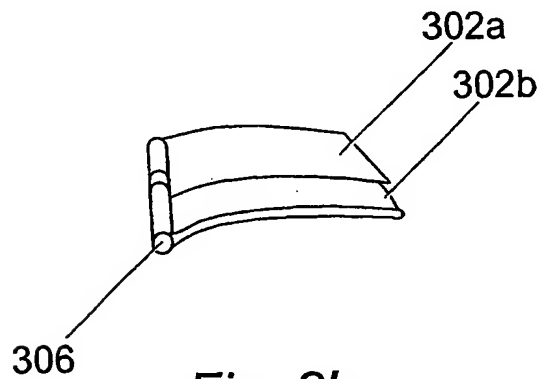


Fig. 7c

7/7

*Fig. 8a**Fig. 8b*

INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 E21B43/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 785 193 A (KINLEY M ET AL) 15 January 1974 (1974-01-15) column 4, line 29 - line 42 column 5, line 21 - line 37 column 6, line 45 - column 7, line 42; figures 4-6	1-11, 13-20, 33, 34
Y	---	12, 35
Y	US 2 627 891 A (CLARK PAUL B) 10 February 1953 (1953-02-10) column 3, line 39 - line 57; figures 1, 4	12, 35
A	US 4 319 393 A (POGONOWSKI IVO C) 16 March 1982 (1982-03-16) figures --- -/-	1, 13, 21, 26

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

- *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

A document member of the same patent family

Date of the actual completion of the international search

19 April 2002

Date of mailing of the international search report

02/05/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Giorgini, G

INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 595 439 A (THOME PAUL) 11 September 1987 (1987-09-11) page 5, line 30 -page 6, line 7; figures 6,7	1-5,13
A	US 3 245 471 A (HOWARD GEORGE C) 12 April 1966 (1966-04-12) figures 1,2	1,13
A	WO 00 37773 A (PETROLINE WELLSYSTEMS LTD ;ASTEC DEV LTD (GB)) 29 June 2000 (2000-06-29) figures	1,13

INTERNATIONAL SEARCH REPORT

PCT/GB02/00356

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3785193	A	15-01-1974	NONE	
US 2627891	A	10-02-1953	NONE	
US 4319393	A	16-03-1982	US 4220034 A US 4309891 A	02-09-1980 12-01-1982
FR 2595439	A	11-09-1987	FR 2595439 A1	11-09-1987
US 3245471	A	12-04-1966	NONE	
WO 0037773	A	29-06-2000	AU 1867900 A AU 1868700 A AU 1868800 A AU 1868900 A AU 1876600 A AU 1876800 A EP 1147287 A2 EP 1141517 A1 EP 1141515 A1 EP 1144802 A2 EP 1151180 A1 EP 1141518 A1 WO 0037766 A2 WO 0037771 A1 WO 0037768 A1 WO 0037767 A2 WO 0037772 A1 WO 0037773 A1 GB 2345308 A GB 2346632 A GB 2346400 A GB 2346909 A GB 2347445 A NO 20012596 A NO 20012597 A NO 20012598 A NO 20012599 A NO 20012600 A NO 20012865 A	12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 12-07-2000 24-10-2001 10-10-2001 10-10-2001 17-10-2001 07-11-2001 10-10-2001 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 29-06-2000 05-07-2000 16-08-2000 09-08-2000 23-08-2000 06-09-2000 27-07-2001 27-07-2001 30-07-2001 30-07-2001 30-07-2001 07-08-2001

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☐ BLACK BORDERS

☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES

☐ FADED TEXT OR DRAWING

☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING

☐ SKEWED/SLANTED IMAGES

☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS

☐ GRAY SCALE DOCUMENTS

☒ LINES OR MARKS ON ORIGINAL DOCUMENT

☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY

☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.